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(54) **Apparatus for virtual endoscopy**

Vorrichtung für virtuelle Endoskopie

Appareil pour endoscopie virtuelle

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to surgical instrument navigation systems and, more particularly, to a system that visually simulates a virtual volumetric scene of a body cavity from a point of view of a surgical instrument residing in a patient.

BACKGROUND OF THE INVENTION

[0002] Precise imaging of portions of the anatomy is an increasingly important technique in the medical and surgical fields. In order to lessen the trauma to a patient caused by invasive surgery, techniques have been developed for performing surgical procedures within the body through small incisions with minimal invasion. These procedures generally require the surgeon to operate on portions of the anatomy that are not directly visible, or can be seen only with difficulty. Furthermore, some parts of the body contain extremely complex or small structures and it is necessary to enhance the visibility of these structures to enable the surgeon to perform more delicate procedures. In addition, planning such procedures required the evaluation of the location and orientation of these structures within the body in order to determine the optimal surgical trajectory.

[0003] Endoscopy is one commonly employed technique for visualizing internal regions of interest within a patient. Flexible endoscopes enable surgeons to visually inspect a region prior to or during surgery. However, flexible endoscopes are relatively expensive, limited in flexibility due to construction and obscured by blood and other biological materials.

[0004] Document WO-A-98/36684 discloses a navigation system having the features of the preamble of claim 1.

[0005] Therefore, it is desirable to provide a cost effective alternative technique for visualizing an internal regions of interest within a patient.

SUMMARY OF THE INVENTION

[0006] In accordance with the present invention, a surgical instrument navigation system is provided that visually simulates a virtual volumetric scene of a body cavity of a patient from a point of view of a surgical instrument residing in the patient as claimed in claim 1. The surgical instrument navigation system generally includes: a surgical instrument, such as a guide wire or catheter; a tracking subsystem that captures real-time position data indicative of the position (location and/or orientation) of the surgical instrument; a data processor which is operable to render a volumetric image of the internal region of interest from a point of view of the surgical instrument; and a display which is operable to display the volumetric image of the patient. The surgical instrument navigation system may also include an imaging device which is operable to capture 2D and/or 3D volumetric scan data representative of an internal region of interest within a given patient.

[0007] Preferred embodiments are disclosed in the dependent claims.

[0008] For a more complete understanding of the invention, reference may be made to the following specification and to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a diagram of an exemplary surgical instrument navigation system in accordance with present invention;

[0010] Figure 2 is a flowchart that depicts a technique for simulating a virtual volumetric scene of a body cavity from a point of view of a surgical instrument positioned within the patient in accordance with the present invention;

[0011] Figure 3 is an exemplary display from the surgical instrument navigation system of the present invention;

[0012] Figure 4 is a flowchart that depicts a technique for synchronizing the display of an indicia or graphical representation of the surgical instrument with cardiac or respiratory cycle of the patient in accordance with the present invention; and

[0013] Figure 5 is a flowchart that depicts a technique for generating four-dimensional image data that is synchronized with the patient in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Figure 1 is a diagram of an exemplary surgical instrument navigation system 10. In accordance with one aspect of the present invention, the surgical instrument navigation system 10 is operable to visually simulate a virtual volumetric scene within the body of a patient, such as an internal body cavity, from a point of view of a surgical instrument 12 residing in the cavity of a patient 13. To do so, the surgical instrument navigation system 10 is primarily comprised of a surgical instrument 12, a data processor 16 having a display 18, and a tracking subsystem 20. The surgical instrument navigation system 10 may further include (or accompanied by) an imaging device 14 that is operable to provide image data to the system.

[0015] The surgical instrument 12 is preferably a relatively inexpensive, flexible and/or steerable catheter that may be of a disposable type. The surgical instrument 12 is modified to include one or more tracking sensors that are detectable by the tracking subsystem 20. It is readily understood that other types of surgical instruments (e.g., a guide wire, a pointer probe, a stent, a seed, an implant, an endoscope, etc.) are also within the scope of the present invention. It is also envisioned that at least some of these surgical instruments may be wireless or have wireless communications links. It is also envisioned that the surgical instruments may encompass medical devices which are used for exploratory purposes, testing purposes or other types of medical procedures.

[0016] Referring to Figure 2, the imaging device 14 is used to capture volumetric scan data 32 representative of an internal region of interest within the patient 13. The three-dimensional scan data is preferably obtained prior to surgery on the patient 13. In this case, the captured volumetric scan data may be stored in a data store associated with the data processor 16 for subsequent processing. However, one skilled in the art will readily recognize that the principles of the present invention may also extend to scan data acquired during surgery. It is readily understood that volumetric scan data may be acquired using various known medical imaging devices 14, including but not limited to a magnetic resonance imaging (MRI) device, a computed tomography (CT) imaging device, a positron emission tomography (PET) imaging device, a 2D or 3D fluoroscopic imaging device, and 2D, 3D or 4D ultrasound imaging devices. In the case of a two-dimensional ultrasound imaging device or other two-dimensional image acquisition device, a series of two-dimensional data sets may be acquired and then assembled into volumetric data as is well known in the art using a two-dimensional to three-dimensional conversion.

[0017] A dynamic reference frame 19 is attached to the patient proximate to the region of interest within the patient 13. To the extent that the region of interest is a vessel or a cavity within the patient, it is readily understood that the dynamic reference frame 19 may be placed within the patient 13. To determine its location, the dynamic reference frame 19 is also modified to include tracking sensors detectable by the tracking subsystem 20. The tracking subsystem 20 is operable to determine position data for the dynamic reference frame 19 as further described below.

[0018] The volumetric scan data is then registered as shown at 34. Registration of the dynamic reference frame 19 generally relates information in the volumetric scan data to the region of interest associated with the patient. This process is referred to as registering image space to patient space. Often, the image space must also be registered to another image space. Registration is accomplished through knowledge of the coordinate vectors of at least three non-collinear points in the image space and the patient space.

[0019] Registration for image guided surgery can be completed by different known techniques. First, point-to-point registration is accomplished by identifying points in an image space and then touching the same points in patient space. These points are generally anatomical landmarks that are easily identifiable on the patient. Second, surface registration involves the user's generation of a surface in patient space by either selecting multiple points or scanning, and then accepting the best fit to that surface in image space by iteratively calculating with the data processor until a surface match is identified. Third, repeat fixation devices entail the user repeatedly removing and replacing a device (i.e., dynamic reference frame, etc.) in known relation to the patient or image fiducials of the patient. Fourth, automatic registration by first attaching the dynamic reference frame to the patient prior to acquiring image data. It is envisioned that other known registration procedures are also within the scope of the present invention, such as that disclosed in U.S. Serial No. 09/274,972, filed on March 23, 1999, entitled "NAVIGATIONAL GUIDANCE VIA COMPUTER-ASSISTED FLUOROSCOPIC IMAGING", now published as US-B-6470207.

[0020] During surgery, the surgical instrument 12 is directed by the surgeon to the region of interest within the patient 13. The tracking subsystem 20 preferably employs electro-magnetic sensing to capture position data 37 indicative of the location and/or orientation of the surgical instrument 12 within the patient. The tracking subsystem 20 may be defined as a localizing device 22 and one or more electro-magnetic sensors 24 may be integrated into the items of interest, such as the surgical instrument 12. In one embodiment, the localizing device 22 is comprised of three or more field generators (transmitters) mounted at known locations on a plane surface and the electro-magnetic sensor (receivers) 24 is further defined as a single coil of wire. The positioning of the field generators (transmitter), and the sensors (receivers) may also be reversed, such that the generators are associated with the surgical instrument 12 and the receivers are positioned elsewhere. Although not limited thereto, the localizing device 22 may be affixed to an underneath side of the operating table that supports the patient.

[0021] In operation, the field generators generate magnetic fields which are detected by the sensor. By measuring the magnetic fields generated by each field generator at the sensor, the location and orientation of the sensor may be computed, thereby determining position data for the surgical instrument 12. Although not limited thereto, exemplary electro-magnetic tracking subsystems are further described in U.S. Patent Nos. 5,913,820; 5,592,939; and 6,374,134. In addition, it is envisioned that other types of position tracking devices are also within the scope of the present invention. For instance, non line-of-sight tracking subsystem 20 may be based on sonic emissions or radio frequency emissions. In another instance, a rigid surgical instrument, such as a rigid endoscope may be tracked using a line-of-sight optical-based tracking subsystem (i.e., LED's, passive markers, reflective markers, etc).

[0022] Position data such as location and/or orientation data from the tracking subsystem 20 is in turn relayed to the data processor 16. The data processor 16 is adapted to receive position/orientation data from the tracking subsystem 20 and operable to render a volumetric perspective image and/or a surface rendered image of the region of interest. The volumetric perspective and/or surface image is rendered 36 from the scan data 32 using rendering techniques well known in the art. The image data may be further manipulated 38 based on the position/orientation data for the surgical instrument 12 received from tracking subsystem 20. Specifically, the volumetric perspective or surface rendered image is rendered from a point of view which relates to position of the surgical instrument 12. For instance, at least one electromagnetic sensor 24 may be positioned at the tip of the surgical instrument 12, such that the image is rendered from a leading point on the surgical instrument. In this way, the surgical instrument navigation system 10 of the present invention is able, for example, to visually simulate a virtual volumetric scene of an internal cavity from the point of view of the surgical instrument 12 residing in the cavity without the use of an endoscope. It is readily understood that tracking two or more electro-magnetic sensors 24 which are embedded in the surgical instrument 12 enables orientation of the surgical instrument 12 to be determined by the system 10.

[0023] As the surgical instrument 12 is moved by the surgeon within the region of interest, its position and orientation are tracked and reported on a real-time basis by the tracking subsystem 20. The volumetric perspective image may then be updated by manipulating 38 the rendered image data 36 based on the position of the surgical instrument 12. The manipulated volumetric perspective image is displayed 40 on a display device 18 associated with the data processor 16. The display 18 is preferably located such that it can be easily viewed by the surgeon during the medical procedure. In one embodiment, the display 18 may be further defined as a heads-up display or any other appropriate display. The image may also be stored by data processor 16 for later playback, should this be desired.

[0024] It is envisioned that the primary perspective image 38 of the region of interest may be supplemented by other secondary images. For instance, known image processing techniques may be employed to generate various multi-planar images of the region of interest. Alternatively, images may be generated from different view points as specified by a user 39, including views from outside of the vessel or cavity or views that enable the user to see through the walls of the vessel using different shading or opacity. In another instance, the location data of the surgical instrument may be saved and played back in a movie format. It is envisioned that these various secondary images may be displayed simultaneously with or in place of the primary perspective image.

[0025] In addition, the surgical instrument 12 may be used to generate real-time maps corresponding to an internal path traveled by the surgical instrument or an external boundary of an internal cavity. Real-time maps are generated by continuously recording the position of the instrument's localized tip and its full extent. A real-time map is generated by the outermost extent of the instrument's position and minimum extrapolated curvature as is known in the art. The map may be continuously updated as the instrument is moved within the patient, thereby creating a path or a volume representing the internal boundary of the cavity. It is envisioned that the map may be displayed in a wire frame form, as a shaded surface or other three-dimensional computer display modality independent from or superimposed on the volumetric perspective image 38 of the region of interest. It is further envisioned that the map may include data collected from a sensor embedded into the surgical instrument, such as pressure data, temperature data or electro-physiological data. In this case, the map may be color coded to represent the collected data.

[0026] Figure 3 illustrates another type of secondary image 28 which may be displayed in conjunction with the primary perspective image 38. In this instance, the primary perspective image is an interior view of an air passage within the patient 13. The secondary image 28 is an exterior view of the air passage which includes an indicia or graphical representation 29 that corresponds to the location of the surgical instrument 12 within the air passage. In Figure 3, the indicia 29 is shown as a crosshairs. It is envisioned that other indicia may be used to signify the location of the surgical instrument in the secondary image. As further described below, the secondary image 28 is constructed by superimposing the indicia 29 of the surgical instrument 12 onto the manipulated image data 38.

[0027] Referring to Figure 4, the display of an indicia of the surgical instrument 12 on the secondary image may be synchronized with an anatomical function, such as the cardiac or respiratory cycle, of the patient. In certain instances, the cardiac or respiratory cycle of the patient may cause the surgical instrument 12 to flutter or jitter within the patient. For instance, a surgical instrument 12 positioned in or near a chamber of the heart will move in relation to the patient's heart beat. In these instance, the indicia of the surgical instrument 12 will likewise flutter or jitter on the displayed image 40. It is envisioned that other anatomical functions which may effect the position of the surgical instrument 12 within the patient are also within the scope of the present invention.

[0028] To eliminate the flutter of the indicia on the displayed image 40, position data for the surgical instrument 12 is acquired at a repetitive point within each cycle of either the cardiac cycle or the respiratory cycle of the patient. As described above, the imaging device 14 is used to capture volumetric scan data 42 representative of an internal region of interest within a given patient. A secondary image may then be rendered 44 from the volumetric scan data by the data processor 16.

[0029] In order to synchronize the acquisition of position data for the surgical instrument 12, the surgical instrument navigation system 10 may further include a timing signal generator 26. The timing signal generator 26 is operable to generate and transmit a timing signal 46 that correlates to at least one of (or both) the cardiac cycle or the respiratory cycle of the patient 13. For a patient having a consistent rhythmic cycle, the timing signal might be in the form of a periodic clock signal. Alternatively, the timing signal may be derived from an electrocardiogram signal from the patient 13. One skilled in the art will readily recognize other techniques for deriving a timing signal that correlate to at least one of the cardiac or respiratory cycle or other anatomical cycle of the patient.

[0030] As described above, the indicia of the surgical instrument 12 tracks the movement of the surgical instrument 12 as it is moved by the surgeon within the patient 13. Rather than display the indicia of the surgical instrument 12 on a real-time basis, the display of the indicia of the surgical instrument 12 is periodically updated 48 based on the timing signal from the timing signal generator 26. In one exemplary embodiment, the timing generator 26 is electrically connected to the tracking subsystem 20. The tracking subsystem 20 is in turn operable to report position data for the surgical instrument 12 in response to a timing signal received from the timing signal generator 26. The position of the indicia of the surgical instrument 12 is then updated 50 on the display of the image data. It is readily understood that other techniques for synchronizing the display of an indicia of the surgical instrument 12 based on the timing signal are within the scope of the present invention, thereby eliminating any flutter or jitter which may appear on the displayed image 52. It is also envisioned that a path (or projected path) of the surgical instrument 12 may also be illustrated on the displayed image data 52.

[0031] In another aspect of the present invention, the surgical instrument navigation system 10 may be further adapted to display four-dimensional image data for a region of interest as shown in Figure 5. In this case, the imaging device 14 is operable to capture volumetric scan data 62 for an internal region of interest over a period of time, such that the region of interest includes motion that is caused by either the cardiac cycle or the respiratory cycle of the patient 13. A volumetric perspective view of the region may be rendered 64 from the volumetric scan data 62 by the data processor 16 as described above. The four-dimensional image data may be further supplemented with other patient data, such as temperature or blood pressure, using coloring coding techniques.

[0032] In order to synchronize the display of the volumetric perspective view in real-time with the cardiac or respiratory cycle of the patient, the data processor 16 is adapted to receive a timing signal from the timing signal generator 26. As described above, the timing signal generator 26 is operable to generate and transmit a timing signal that correlates to either the cardiac cycle or the respiratory cycle of the patient 13. In this way, the volumetric perspective image may be synchronized 66 with the cardiac or respiratory cycle of the patient 13. The synchronized image 66 is then displayed 68 on the display 18 of the system. The four-dimensional synchronized image may be either (or both of) the primary image rendered from the point of view of the surgical instrument or the secondary image depicting the indicia of the position of the surgical instrument 12 within the patient 13. It is readily understood that the synchronization process is also applicable to two-dimensional image data acquire over time.

[0033] To enhance visualization and refine accuracy of the displayed image data, the surgical navigation system can use prior knowledge such as the segmented vessel structure to compensate for error in the tracking subsystem or for inaccuracies caused by an anatomical shift occurring since acquisition of scan data. For instance, it is known that the surgical instrument 12 being localized is located within a given vessel and, therefore should be displayed within the vessel. Statistical methods can be used to determine the most likely location within the vessel with respect to the reported location and then compensate so the display accurately represents the instrument 12 within the center of the vessel. The center of the vessel can be found by segmenting the vessels from the three-dimensional datasets and using commonly known imaging techniques to define the centerline of the vessel tree. Statistical methods may also be used to determine if the surgical instrument 12 has potentially punctured the vessel. This can be done by determining the reported location is too far from the centerline or the trajectory of the path traveled is greater than a certain angle (worse case 90 degrees) with respect to the vessel. Reporting this type of trajectory (error) is very important to the clinicians. The tracking along the center of the vessel may also be further refined by correcting for motion of the respiratory or cardiac cycle, as described above.

[0034] The surgical instrument navigation system of the present invention may also incorporate atlas maps. It is envisioned that three-dimensional or four-dimensional atlas maps may be registered with patient specific scan data or generic anatomical models. Atlas maps may contain kinematic information (e.g., heart models) that can be synchronized with four-dimensional image data, thereby supplementing the real-time information. In addition, the kinematic information may be combined with localization information from several instruments to provide a complete four-dimensional model of organ motion. The atlas maps may also be used to localize bones or soft tissue which can assist in determining placement and location of implants.

[0035] While the invention has been described in its presently preferred form, it will be understood that the invention is capable of modification without departing from the invention as set forth in the appended claims.

Claims

1. A navigation system to track a surgical instrument relative to a patient, comprising:

    a tracking subsystem operable to capture in real-time position data indicative of the position of the surgical instrument;

a data processor adapted to receive scan data representative of a region of interest of a given patient and the position data from the tracking subsystem, the data processor being operable to render a volumetric image of the region of interest from a point of view of the surgical instrument, the image being derived from the scan data;

a display in data communication with the data processor, the display being operable to display the volumetric image of the patient from the perspective of the surgical instrument; **characterized by**

an accuracy enhancing subsystem operable to enhance visualization and refine accuracy of the displayed image data by statistical methods to determine if the surgical instrument has potentially punctured the vessel such as by determining the reported location is too far from the centerline or the trajectory of the path traveled is greater than a certain angle with respect to the vessel;

wherein the accuracy enhancing subsystem is operable to compensate for an error in the tracking subsystem when tracking the surgical instrument through a selected vessel.

2. The navigation system of Claim 1, further comprising an imaging system operable to acquire scan image data separate from the instrument and the displayed rendered volumetric image based on the captured real-time position data of the instrument.

3. The navigation system of Claim 2, wherein the accuracy enhancing subsystem is operable to compensate for inaccuracies caused by anatomical shift caused during acquisition of the scanned data including determining the appropriate rendering for the display from the perspective of the surgical instrument.

4. The navigation system of Claim 2, wherein said data processor is operable to segment the scan image data to define a region and the accuracy enhancing subsystem is operable to perform error correction methods to correctly display a region in the segmented region representing the location of the surgical instrument tracked with the tracking subsystem.

5. The navigation system of any one of the preceding claims further comprising:

a timing signal generator operable to generate and transmit a timing signal that correlates to at least one anatomical function of the patient;

wherein the tracking subsystem is operable to receive the timing signal from the timing signal generator, the tracking subsystem operable to capture position data indicative of the position of the surgical instrument and to report the position data in response to the timing signal received from the timing signal generator;

wherein the data processor is adapted to receive scan image data representative of an internal region of interest within a given patient and the position data from the tracking subsystem, the data processor being operable to render a volumetric perspective image of the internal region of interest from the scan image data and to superimpose an indicia of the surgical instrument onto the volumetric perspective image based on the position data received from the tracking subsystem.

6. The navigation system of Claim 5, wherein the data processor is operable to create a map of the area through which the surgical instrument is moved by tracking the real time location and orientation of the surgical instrument over time;
wherein the map is displayed on the display.

7. The navigation system of Claims 1 - 4, wherein the scan data can be obtained preoperatively, intra-operatively, from an atlas map, or combinations thereof.

8. The navigation system of Claims 1 - 4, wherein the rendered image displayed on the display is operable to be from the point of view of the surgical instrument.

9. The navigation system of Claims 1 - 4 wherein said tracking subsystem includes wireless communication with the surgical instrument.

10. The navigation system of Claims 1 - 4 wherein the data processor is operable to render at least one of a volumetric perspective image, a surface rendered image, or combinations thereof.

11. The navigation system of Claims 1 - 4 further comprising:

a secondary image;

wherein the data processor is operable to render a secondary image of the area of interest; and

wherein the display is operable to display the rendered secondary image.

12. The navigation system of Claims 1 - 4 wherein the data processor is operable to render a four dimensional image of the patient;
wherein a change of the patient over time is illustrated on the rendered image.

13. The navigation system of any of the preceding claims, wherein the accuracy enhancing subsystem is arranged to report a trajectory error.

14. The navigation system according to claim 13, wherein the trajectory error is determined based upon image data of the body and a reported location of the surgical instrument.

15. The navigation system of any one of the preceding claims, wherein the accuracy enhancing subsystem is operable to use prior knowledge such as a segmented vessel structure to compensate for error in the tracking subsystem or for inaccuracies caused by an anatomical shift occurring since acquisition of the scan image data.

16. The navigation system of Claim 14, wherein prior knowledge includes that the surgical instrument being tracked with the tracking subsystem is located within a given vessel and therefore should be displayed within the given vessel, wherein the accuracy enhancing subsystem is operable to use statistical methods to determine a most likely location within the given vessel with respect to a reported location of the surgical instrument and then the accuracy enhancing subsystem is operable to compensate the reported location with the statistically determined location so the display accurately displays the location of the surgical instrument within a center of the given vessel.

17. The navigation system of Claim 15, wherein the center of the given vessel is found by segmenting a vessel from scan image data to define a centerline of a vessel tree.

18. The navigation system of Claim 17, wherein the accuracy enhancing subsystem is further operable to determine the tracked location of the surgical instrument along the center of the given vessel by correcting for motion of a respiratory cycle or cardiac cycle.

Patentansprüche

1. Navigationssystem zum Nachführen eines chirurgischen Instruments relativ zu einem Patienten, das Folgendes umfasst:

ein Nachführ-Teilsystem, das dafür geeignet ist, in Echtzeit Positionsdaten zu erfassen, die die Position des chirurgischen Instruments anzeigen;
einen Datenprozessor, der dafür ausgelegt ist, Abtastdaten, die für eine interessierende Region eines bestimmten Patienten repräsentativ sind, und die Positionsdaten des Nachführ-Teilsystems zu empfangen,
wobei der Datenprozessor dafür geeignet ist, ein volumetrisches Bild der interessierenden Region aus der Sicht des chirurgischen Instruments zu errechnen, wobei das Bild aus den Abtastdaten abgeleitet wird;
eine Anzeige, die im Datenaustausch mit dem Datenprozessor steht,
wobei die Anzeige dafür geeignet ist, das volumetrische Bild des Patienten aus der Perspektive des chirurgischen Instruments anzuzeigen;
gekennzeichnet durch
ein Genauigkeitserhöhungs-Teilsystem, das dafür geeignet ist, die visuelle Darstellung zu verbessern und die Genauigkeit der angezeigten Bilddaten **durch** statistische Verfahren zu erhöhen, um zu bestimmen, ob das chirurgische Instrument möglicherweise das Gefäß durchstochen hat, wie zum Beispiel anhand des Bestimmens, dass die gemeldete Position zu weit von der Mittellinie entfernt ist, oder dass die Trajektorie des zurückgelegten Pfades größer ist als ein bestimmter Winkel mit Bezug auf das Gefäß,
wobei das Genauigkeitserhöhungs-Teilsystem dafür geeignet ist, einen Fehler in dem Nachführ-Teilsystem zu kompensieren, wenn das chirurgische Instrument **durch** ein ausgewähltes Gefäß nachgeführt wird.

2. Navigationssystem nach Anspruch 1, das des Weiteren ein Bildgabesystem umfasst, das dafür geeignet ist, Abtastbilddaten separat von dem Instrument und dem angezeigten errechneten volumetrischen Bild auf der Grundlage die erfassten Echtzeit-Positionsdaten des Instruments zu erfassen.

3. Navigationssystem nach Anspruch 2, wobei das Genauigkeitserhöhungs-Teilsystem dafür geeignet ist, Ungenauigkeiten zu kompensieren, die durch eine anatomische Verschiebung verursacht werden, die während der Erfassung der abgetasteten Daten verursacht wird, einschließlich des Bestimmens der entsprechenden Errechnung für die Anzeige aus der Perspektive des chirurgischen Instruments.

4. Navigationssystem nach Anspruch 2, wobei der Datenprozessor dafür geeignet ist, die Abtastbilddaten zu segmentieren, um eine Region zu definieren, und das Genauigkeitserhöhungs-Teilsystem dafür geeignet ist, Fehlerkorrekturverfahren auszuführen, um eine Region in der segmentierten Region korrekt anzuzeigen, die die Position des chirurgischen Instruments darstellt, das mit dem Nachführ-Teilsystem nachgeführt wird.

5. Navigationssystem nach einem der vorangehenden Ansprüche, das des Weiteren Folgendes umfasst:

einen Zeitsteuersignalgenerator, der dafür ge-

eignet ist, ein Zeitsteuersignal zu generieren und zu senden, das mit mindestens einer anatomischen Funktion des Patienten korreliert;
wobei das Nachführ-Teilsystem dafür geeignet ist, das Zeitsteuersignal von dem Zeitsteuersignalgenerator zu empfangen, das Nachführ-Teilsystem dafür geeignet ist, Positionsdaten zu erfassen, die die Position des chirurgischen Instruments anzeigen, und die Positionsdaten in Reaktion auf das Zeitsteuersignal, das von dem Zeitsteuersignalgenerator kommend empfangen wurde, zu berichten;
wobei der Datenprozessor dafür geeignet ist, Abtastbilddaten, die für eine innere interessierende Region innerhalb eines bestimmten Patienten repräsentativ sind, und die Positionsdaten von dem Nachführ-Teilsystem zu empfangen, wobei der Datenprozessor dafür geeignet ist, ein volumetrisches perspektivisches Bild der inneren interessierenden Region aus den Abtastbilddaten zu errechnen und
auf der Grundlage der Positionsdaten, die von dem Nachführ-Teilsystem kommend empfangen wurden, ein Symbol des chirurgischen Instruments über das volumetrische perspektivische Bild zu legen.

6. Navigationssystem nach Anspruch 5, wobei der Datenprozessor dafür geeignet ist, eine Karte des Bereichs, durch den das chirurgische Instrument bewegt wird, durch Nachführen der Echtzeit-Position und Ausrichtung des chirurgischen Instruments im zeitlichen Verlauf zu erstellen;
wobei die Karte auf der Anzeige angezeigt wird.

7. Navigationssystem nach den Ansprüchen 1-4, wobei die Abtastdaten präoperativ, intraoperativ, aus einer Atlaskarte oder Kombinationen davon erhalten werden können.

8. Navigationssystem nach den Ansprüchen 1-4, wobei das errechnete Bild, das auf der Anzeige angezeigt wird, dafür geeignet ist, die Perspektive des chirurgischen Instruments wiederzugeben.

9. Navigationssystem nach den Ansprüchen 1-4, wobei das Nachführ-Teilsystem eine drahtlose Kommunikation mit dem chirurgischen Instrument enthält.

10. Navigationssystem nach den Ansprüchen 1-4, wobei der Datenprozessor dafür geeignet ist, ein volumetrisches perspektivisches Bild und/oder ein oberflächengerendertes Bild oder Kombinationen davon zu errechnen.

11. Navigationssystem nach den Ansprüchen 1-4, das des Weiteren Folgendes umfasst:

ein sekundäres Bild;
wobei der Datenprozessor dafür geeignet ist, ein sekundäres Bild des interessierenden Bereichs zu errechnen; und
wobei die Anzeige dafür geeignet ist, das errechnete sekundäre Bild anzuzeigen.

12. Navigationssystem nach den Ansprüchen 1-4, wobei der Datenprozessor dafür geeignet ist, ein vierdimensionales Bild des Patienten zu errechnen;
wobei eine Veränderung des Patienten im zeitlichen Verlauf auf dem errechneten Bild veranschaulicht wird.

13. Navigationssystem nach einem der vorangehenden Ansprüche, wobei das Genauigkeitserhöhungs-Teilsystem dafür ausgelegt ist, einen Trajektoriefehler zu melden.

14. Navigationssystem nach Anspruch 13, wobei der Trajektoriefehler auf der Basis von Bilddaten des Körpers und einer berichteten Position des chirurgischen Instruments bestimmt wird.

15. Navigationssystem nach einem der vorangehenden Ansprüche, wobei das Genauigkeitserhöhungs-Teilsystem dafür geeignet ist, vorheriges Wissen, wie zum Beispiel eine segmentierte Gefäßstruktur, zu nutzen, um Fehler in dem Nachführ-Teilsystem oder Ungenauigkeiten zu kompensieren, die seit der Erfassung der Abtastbilddaten durch eine anatomische Verschiebung verursacht wurden.

16. Navigationssystem nach Anspruch 14, wobei das vorherige Wissen enthält, dass sich das chirurgische Instrument, das mit dem Nachführ-Teilsystem nachgeführt wird, innerhalb eines bestimmten Gefäßes befindet und daher innerhalb des bestimmten Gefäßes angezeigt werden sollte, wobei das Genauigkeitserhöhungs-Teilsystem dafür geeignet ist, statistische Verfahren zu nutzen, um eine wahrscheinlichste Position innerhalb des bestimmten Gefäßes mit Bezug auf eine berichtete Position des chirurgischen Instruments zu bestimmen, und das Genauigkeitserhöhungs-Teilsystem dann dafür geeignet ist, die berichtete Position mit der statistisch bestimmten Position zu kompensieren, so dass die Anzeige die Position des chirurgischen Instruments innerhalb einer Mitte des bestimmten Gefäßes genau anzeigt.

17. Navigationssystem nach Anspruch 15, wobei die Mitte des bestimmten Gefäßes durch Segmentieren eines Gefäßes anhand von Abtastbilddaten gefunden wird, um eine Mittellinie eines Gefäßbaums zu definieren.

18. Navigationssystem nach Anspruch 17, wobei das

Genauigkeitserhöhungs-Teilsystem des Weiteren dafür geeignet ist, die nachgeführte Position des chirurgischen Instruments entlang der Mitte des bestimmten Gefäßes durch Korrigieren um die Bewegung eines Atmungszyklus oder Herzzyklus zu bestimmen.

Revendications

1. Système de navigation pour suivre un instrument chirurgical par rapport à un patient, comprenant :

    un sous-système de suivi utilisable pour acquérir des données de position en temps réel indicatives de la position de l'instrument chirurgical ;
    un processeur de données apte à recevoir des données de balayage représentatives d'une région d'intérêt d'un patient donné et les données de position en provenance du sous-système de suivi, le processeur de données étant utilisable pour effectuer le rendu d'une image volumétrique de la région d'intérêt du point de vue de l'instrument chirurgical, l'image étant dérivée des données de balayage
    un affichage en communication de données avec le processeur de données, l'affichage étant utilisable pour afficher l'image volumétrique du patient dans la perspective de l'instrument chirurgical ; **caractérisé par**
    un sous-système d'amélioration de précision utilisable pour améliorer une visualisation et affiner une précision des données d'image affichées par des méthodes statistiques pour déterminer si l'instrument chirurgical a potentiellement perforé le vaisseau, comme en déterminant si l'emplacement rapporté est trop éloigné de la ligne médiane ou si la trajectoire du chemin parcouru est supérieure à un certain angle par rapport au vaisseau ;
    dans lequel le sous-système d'amélioration de précision est utilisable pour compenser une erreur dans le sous-système de suivi lors du suivi de l'instrument chirurgical à travers un vaisseau sélectionné.

2. Système de navigation selon la revendication 1, comprenant en outre un système d'imagerie utilisable pour acquérir des données d'image de balayage distinctes de l'instrument et l'image volumétrique rendue affichée sur la base des données de position en temps réel acquises de l'instrument.

3. Système de navigation selon la revendication 2, dans lequel le sous-système d'amélioration de précision est utilisable pour compenser des imprécisions provoquées par un déplacement anatomique causé pendant l'acquisition des données balayées comprenant la détermination du rendu approprié pour l'affichage dans la perspective de l'instrument chirurgical.

4. Système de navigation selon la revendication 2, dans lequel ledit processeur de données est utilisable pour segmenter les données d'image de balayage afin de définir une région et le sous-système d'amélioration de précision est utilisable pour effectuer des méthodes de correction d'erreur pour afficher correctement une région dans la région segmentée représentant l'emplacement de l'instrument chirurgical suivi avec le sous-système de suivi.

5. Système de navigation selon l'une quelconque des revendications précédentes, comprenant en outre :

    un générateur de signal de synchronisation utilisable pour générer et
    transmettre un signal de synchronisation qui se corrèle avec au moins une fonction anatomique du patient ;
    dans lequel le sous-système de suivi est utilisable pour recevoir le signal de synchronisation en provenance du générateur de signal de synchronisation, le sous-système de suivi étant utilisable pour acquérir des données de position indicatives de la position de l'instrument chirurgical et pour rapporter les données de position en réponse au signal de synchronisation reçu en provenance du générateur de signal de synchronisation ;
    dans lequel le processeur de données est apte à recevoir des données d'image de balayage représentatives d'une région interne d'intérêt à l'intérieur d'un patient donné et les données de position en provenance du sous-système de suivi, le processeur de données étant utilisable pour effectuer le rendu d'une image en perspective volumétrique de la région interne d'intérêt à partir des données d'image de balayage et
    pour superposer un indice de l'instrument chirurgical sur l'image en perspective volumétrique sur la base des données de position reçues en provenance du sous-système de suivi.

6. Système de navigation selon la revendication 5, dans lequel le processeur de données est utilisable pour créer une carte de la zone dans laquelle l'instrument chirurgical est déplacé en suivant l'emplacement en temps réel et l'orientation en temps réel de l'instrument chirurgical au fil du temps ;
dans lequel la carte est affichée sur l'affichage.

7. Système de navigation selon les revendications 1 à 4, dans lequel les données de balayage peuvent être obtenues avant l'intervention, au cours de l'intervention, à partir d'une carte d'atlas ou par des combi-

naisons de ce qui précède.

8. Système de navigation selon les revendications 1 à 4, dans lequel l'image rendue affichée sur l'affichage est utilisable pour être à partir du point de vue de l'instrument chirurgical.

9. Système de navigation selon les revendications 1 à 4, dans lequel ledit sous-système de suivi comprend une communication sans fil avec l'instrument chirurgical.

10. Système de navigation selon les revendications 1 à 4, dans lequel le processeur de données est utilisable pour effectuer le rendu d'au moins l'une d'une image en perspective volumétrique, d'une image rendue de surface ou de combinaisons de celles-ci.

11. Système de navigation selon les revendications 1 à 4, comprenant en outre :

une image secondaire ;
dans lequel le processeur de données est utilisable pour effectuer le rendu d'une image secondaire de la zone d'intérêt ; et
dans lequel l'affichage est utilisable pour afficher l'image secondaire rendue.

12. Système de navigation selon les revendications 1 à 4, dans lequel le processeur de données est utilisable pour effectuer le rendu d'une image à quatre dimensions du patient ;
dans lequel un changement du patient au fil du temps est illustré sur l'image rendue.

13. Système de navigation selon l'une quelconque des revendications précédentes, dans lequel le sous-système d'amélioration de précision est agencé pour rapporter une erreur de trajectoire.

14. Système de navigation selon la revendication 13, dans lequel l'erreur de trajectoire est déterminée sur la base de données d'image du corps et d'un emplacement rapporté de l'instrument chirurgical.

15. Système de navigation selon l'une quelconque des revendications précédentes, dans lequel le sous-système d'amélioration de précision est utilisable pour employer des connaissances préalables comme une structure de vaisseau segmentée afin de compenser toute erreur du sous-système de suivi ou toute imprécision provoquée par un déplacement anatomique survenant depuis l'acquisition des données d'image de balayage.

16. Système de navigation selon la revendication 14, dans lequel les connaissances préalables incluent que l'instrument chirurgical suivi avec le sous-système de suivi est situé à l'intérieur d'un vaisseau donné et doit donc être affiché à l'intérieur du vaisseau donné, dans lequel le sous-système d'amélioration de précision est utilisable pour employer des méthodes statistiques afin de déterminer l'emplacement le plus probable à l'intérieur du vaisseau donné par rapport à un emplacement rapporté de l'instrument chirurgical, puis le sous-système d'amélioration de précision est utilisable pour compenser l'emplacement rapporté avec l'emplacement déterminé statistiquement de sorte que l'affichage affiche avec précision l'emplacement de l'instrument chirurgical à l'intérieur d'un centre du vaisseau donné.

17. Système de navigation selon la revendication 15, dans lequel le centre du vaisseau donné est trouvé en segmentant un vaisseau à partir de données d'image de balayage pour définir une ligne médiane d'une arborescence de vaisseaux.

18. Système de navigation selon la revendication 17, dans lequel le sous-système d'amélioration de précision est en outre utilisable pour déterminer l'emplacement suivi de l'instrument chirurgical le long du centre du vaisseau donné en corrigeant tout mouvement d'un cycle respiratoire ou d'un cycle cardiaque.

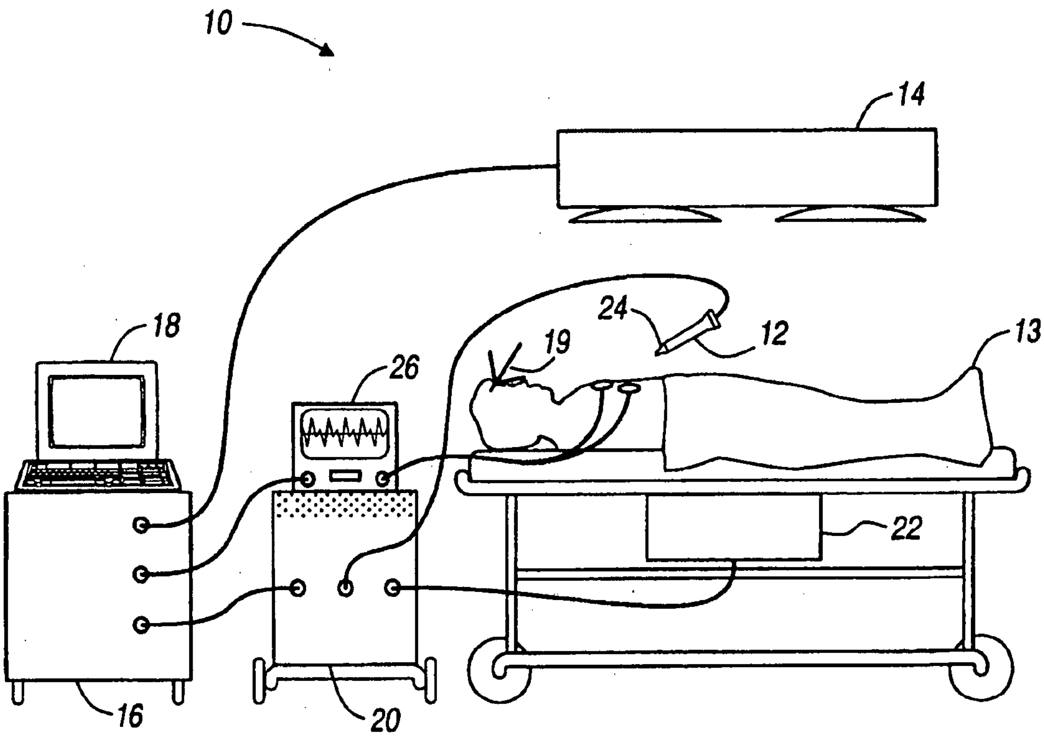

FIGURE- 1

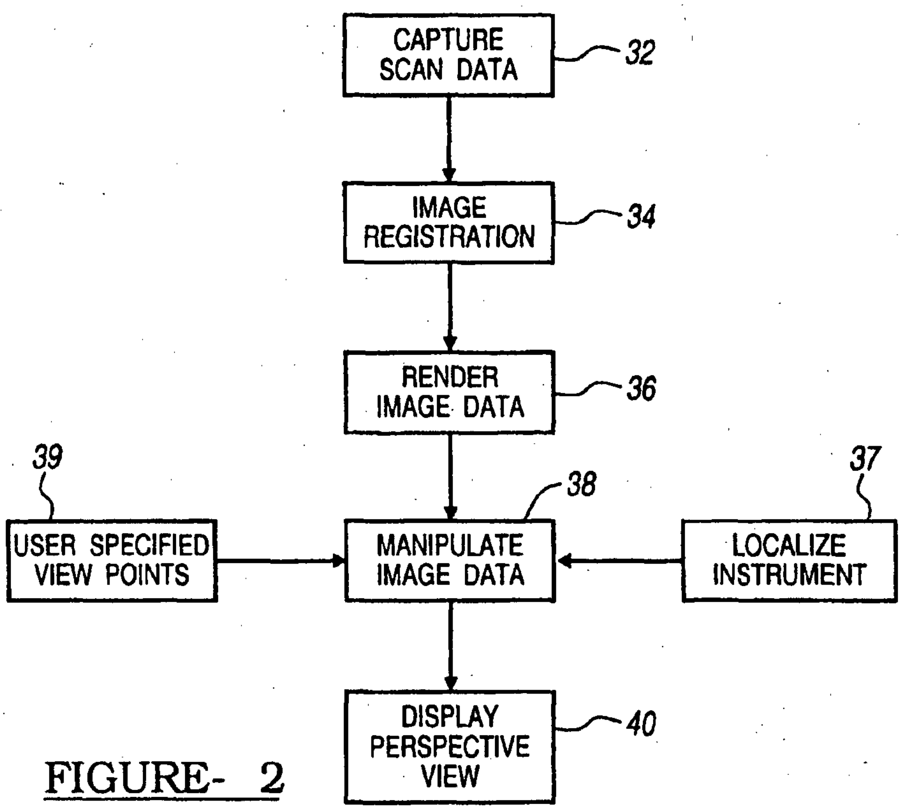

FIGURE- 2

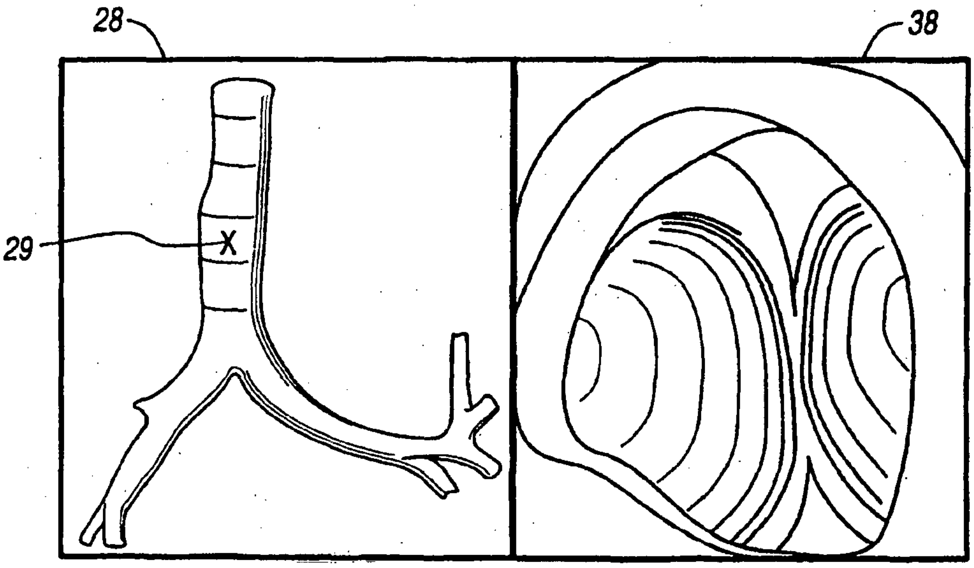

FIGURE- 3

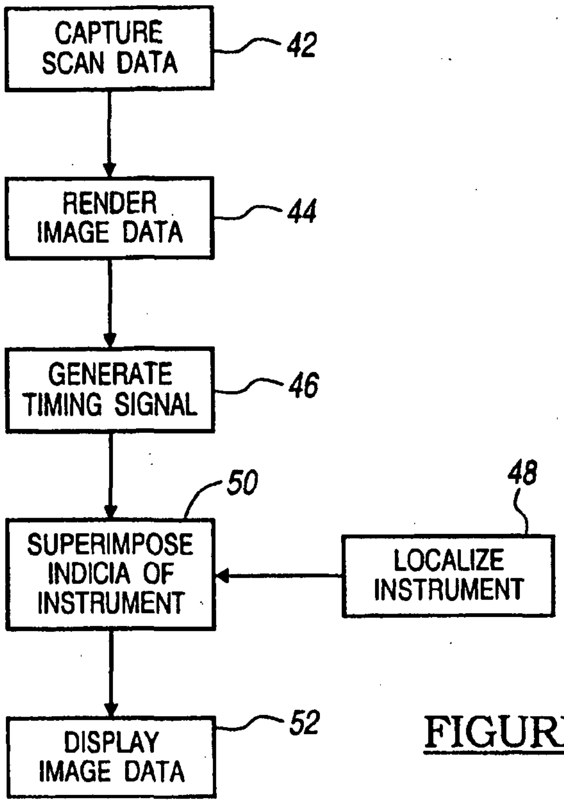

FIGURE- 4

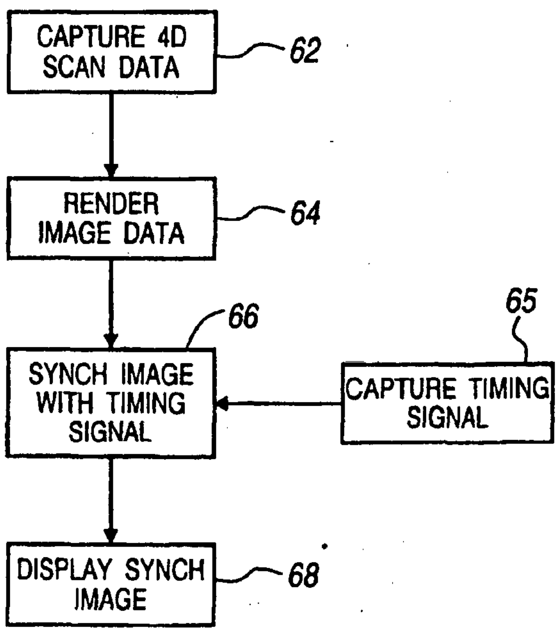

FIGURE- 5

REFERENCES CITED IN THE DESCRIPTION

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